

Green Technology: Biocomposite Cellphone Casing from Coconut Shells (*Cocos nucifera L.*) and Mangosteen Peels (*Garcinia mangostana L.*)

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Abstract—This experimental study assessed the potential of coconut shells and mangosteen peels in biocomposite formulations for eco-friendly cellphone cases. Three mixtures with varying proportions were fabricated and tested for weight, thickness, tensile strength, flexural strength, impact resistance, and biodegradability across ten trials per mixture. Mixture three had the lowest average weight at 5.4 g, while Mixtures one and two both averaged 5.7 g. Mixture three recorded the greatest thickness at 50.7 mm; ANOVA confirmed significant variation. In mechanical tests, Mixture three showed the highest tensile strength at 238.43 kPa, followed by Mixture two (203.98 kPa) and Mixture one (159.19 kPa), with ANOVA indicating significance. Mixture one led in flexural strength at 10,027 kPa; Kruskal-Wallis results confirmed significant differences. Mixture three also had the highest impact resistance at 0.0706 J, with significant variation verified by Kruskal-Wallis. Biodegradability testing showed Mixture three had the highest degradation rate at 80.5%, while Mixtures one and two each showed 74.5%. These findings identify Mixture three as the most effective in combining durability and environmental performance for cellphone casing product. The study supports the use of agricultural waste in producing eco-friendly cellphone casings, offering a viable alternative to conventional plastics and recommends incorporating a retardant, optimizing molding conditions, and manufacturing simple products like coasters can improve biocomposite quality, production efficiency, and commercial appeal.

Keywords— Biocomposite, cellphone casing, coconut shells, green technology, mangosteen peels, biocomposite mold, Low-Density Polyethylene (LDPE)

I. INTRODUCTION

The quest for sustainable materials has increasingly focused on utilizing agricultural and organic wastes, with recent research underscoring their potential as valuable resources for bio composites. These materials, often regarded as waste, are being innovatively repurposed to tackle environmental challenges and meet the rising demand for eco-friendly products. The drive to integrate such materials into sustainable solutions reflects a broader trend towards minimizing environmental impact while maximizing resource efficiency.

A comprehensive review by Hossain et al. (2023) in the Journal of Cleaner Production examines various agricultural wastes used in bio composite materials. The review details the different processing methods, benefits, and applications of these by-products, offering a broad perspective on their transformation into sustainable materials. It highlights how

agricultural wastes can play a significant role in reducing environmental waste and advancing sustainability in product design. By exploring diverse types of agricultural waste, the study illustrates their potential to replace conventional composites and foster more eco-friendly manufacturing practices.

Coconut shells, a prevalent agricultural waste, have been thoroughly analyzed by Lee and Kim (2022) in Waste Management. Their research explores the properties, processing techniques, and engineering applications of coconut shells, demonstrating their effectiveness in durable composite materials. The study confirms that coconut shells possess beneficial attributes such as strength and resilience, making them suitable for a range of engineering uses.

On the other hand, Sundararajan et al. (2021) investigate the potential of mangosteen peels as a raw material for bio composites in Industrial Crops and Products. Their research evaluates the mechanical properties of mangosteen peels and their applicability in different composite applications. By showcasing the versatility and effectiveness of mangosteen peels, this study contributes to a deeper understanding of how various agricultural wastes can be utilized to create effective and sustainable materials.

Research studies have mainly focused on the applications of coconut shells and mangosteen peels in products like activated carbon, medical products, and composites. However, there's a significant gap in research exploring the potential of these materials for everyday products like phone cases. Few studies have investigated how the mechanical properties, manufacturing processes, and cost-efficiency of these materials could be combined to create durable and eco-friendly phone cases.

This study addresses this gap by introducing a new approach to sustainable production, utilizing both coconut shells and mangosteen peels in the fabrication of phone cases. This study reduces waste from two sources while offering an eco-friendly alternative for a commonly used accessory. By employing these waste materials, the study promotes sustainable waste management practices, minimizes the environmental impact of agricultural waste, and offers a practical solution through everyday products.

II. METHODOLOGY

A. Collection of Raw Materials

The coconut shells and mangosteen peels, which were considered waste and no longer needed, were provided by local market vendors in Curuan, Zamboanga City. The first step was material preparation, which involved cleaning, drying, and grinding the coconut shells and mangosteen peels. The researcher began the process by gathering the raw materials for the biocomposite mixture. The coconut shells were then cut and chopped into pieces using a machete, while the mangosteen peels were washed and dried in the sun for three days before being placed in an oven for about two hours at a temperature of 250°C. Afterward, the materials were transferred into a metal container, and the researcher went to the local market in Curuan, Zamboanga City, where the raw materials were milled. The grinding of the raw materials at the local market in Curuan was carried out by skilled laborers or service providers specializing in milling agricultural waste. The coconut shells and mangosteen peels were placed in the grinder, and the grinding process took one hour to turn the dried materials into a fine powder. Finally, the powder was sieved using sieve No. 40 to ensure a uniform particle size.

B. Formulate Proportions for Biocomposites

The first mixture utilized a 35:35:30 ratio, consisting of 294 g of coconut shell powder, 252 g of mangosteen peel powder, and 338.4 g of LDPE. The second mixture followed a 49:21:30 ratio, consisting of 411.6 g of coconut shell powder, 151.2 g of mangosteen peel powder, and 338.4 g of LDPE. Finally, the third mixture used a 28:42:30 ratio, consisting of 235.2 g of coconut shell powder, 303.4 g of mangosteen peel powder, and 338.4 g of LDPE. The biocomposite strips measured 100 mm x 20 mm x 10 mm, and a total of 120 sample strips were tested. These carefully selected mixtures were intended to ensure both durability and eco- friendliness.

C. Composite Mixing

The next step was composite mixing. The LDPE plastic was cut into small, manageable pieces and then placed them in an aluminum pot on the gas stove burner. The gas stove was slightly increased to medium heat, and the mixture was stirred to distribute the heat evenly. The LDPE plastic began melting at 250°C and was stirred continuously until it became liquid. After an hour, the plastics were fully melted and ready for molding.

D. Molding the Composite Mixture

A biocomposite mold shown in Figure 1 with dimensions of 200 mm by 200 mm by 30 mm is made to create 40 uniform sample strips per molding unit. Three molds were used to create a total of 120 strips, with each contributing 40 strips equally. This ensures each mold makes one-third of the samples, maintaining quality and accuracy during testing.

E. Cooling and Finishing

Once the molding of the biocomposite was completed, it was allowed to cool to approximately room temperature about 25°C below its solidification point of around 60°C, to ensure it

had sufficiently solidified. After it became rigid, it was carefully removed from the mold. The mixture was then sliced and trimmed to a size of 100 mm by 20 mm by 10 mm in 120 sample strips for testing.



Figure 1. Biocomposite mold



Figure 2. Biocomposite strip sample of mixture 1

F. Testing of the Biocomposites

Following the fabrication of the biocomposite samples, a series of tests was conducted to evaluate their mechanical properties, including tensile strength, flexural strength, and impact resistance. These tests were essential to determine the suitability of each biocomposite for cellphone casing fabrication. Testing commenced as soon as the product samples were completed, with test specimens selected randomly to ensure unbiased representation. Each biocomposite sample was cut uniformly into 100 mm × 10 mm sizes, with a total of 40 samples produced for each proportion.

G. Selecting the Suitable Mixture for Cellphone Casing Fabrication

After analyzing the results, the most suitable biocomposite mixture based on its strength and durability was chosen for cellphone casing casting. The process was repeated, but this time, the biocomposite mixture was poured into the cellphone casing mold with dimensions of 20 cm by 14 cm by 2 cm. Afterwards, the product was placed in a ventilated area to dry. The process was then repeated for the two samples.



Figure 3. Cellphone Casing Mold

H. Testing and Characterization

The testing and characterization phase evaluated the performance of biocomposite materials made from coconut shells and mangosteen peels for cellphone case fabrication. Standardized tests assessed the physical, mechanical and biodegradability of the mixtures. The results validated their potential as sustainable alternatives, supporting eco-friendly material innovation.

Physical Properties

Weight

The weight test focuses on the bio-composite made of coconut shells and mangosteen peels regarding mass, such that it's lightweight but heavy-duty. In terms of comparing, a digital scale is utilized. 30 samples will be use, to ensures if weight becomes a determinant for usability, creating an eco-friendly, functional, and comfortable alternative to standard cases.

Thickness

The thickness of the biocomposites was measured after the drying process using a digital caliper. The thickness in percentage was then calculated by comparing the original thickness after molding to the thickness after drying using the formula below.

$$\text{Thickness percentage} = \left(\frac{\text{Initial thickness} - \text{Final thickness}}{\text{Initial thickness}} \right) \times 100 \quad (1)$$

Mechanical Properties

Tensile Strength

The tensile properties of rubber-like materials, including bioplastics, were evaluated using a standard testing procedure. Following the method by Gupta et al. (2021), the researcher measured the sample strip's thickness and width with a caliper, converted the values to meters, and recorded them to determine the cross-sectional area. The specimen was then secured in metal clamps to prevent slippage, with a string attached to one clamp and a spring scale hooked to the loop.

$$\text{Tensile strength} = \frac{\text{Force}}{\text{Width} \times \text{Thickness}} \quad (2)$$

Flexural Strength

The flexural strength of a material can be determined using a three-point bending test, a method adapted from standard testing procedures such as those outlined by ASTM D790. In

this test, a biocomposite strip is placed on two supports with a known span length, and a load is applied at the center until fracture or significant deformation occurs. The specimen was cut to dimensions and the maximum load (Force) before failure is recorded. The span length (L), width (b), and thickness (d) of the specimen are also measured to compute flexural strength below is the formula used.

$$\text{Flexural strength} = \frac{3FL}{\text{width} \times \text{thickness}} \quad (3)$$

Impact Resistance

To evaluate the impact resistance of a biocomposite, a drop test procedure can be followed where the biocomposite strip is dropped from a height of 4 feet (1.2 meters) onto a rigid, flat surface. The sample was free of defects, and the height was measured accurately for consistent results. After each drop, the biocomposite is inspected for visible damage such as cracks, deformations, or breakage, with the damage categorized based on severity. Multiple drops were performed to assess how the material withstands repeated impacts. The extent of damage is recorded and analyzed, including any cracks or deformations, to determine if the case still offers adequate protection. For more advanced testing, the energy absorbed during the impact can be quantified using the formula:

$$E = m \cdot g \cdot h \quad (4)$$

Biodegradability Test

By exposing the samples to regulated environmental conditions and monitoring their rate of degradation over time, the biodegradability of the samples was evaluated. The sustainability and possible environmental impact of the biocomposite were ascertained with the aid of this analysis. After being weighed and placed on an identically sized plastic cover, the samples were buried 8 cm below the surface of the ground (Kam & Iyer, 2019). After a week, the three mixtures were removed and cleaned, and any signs of biodegradation were noted in addition to their visual appearance. There were noticeable differences in the product's weight, texture, color, and appearance. The sample's initial weight was ascertained prior to burial, and the sample's final weight was calculated in order to calculate the rate of material degradation.

$$\text{Degradation rate} = \left(\frac{\text{Initial weight} - \text{Final weight}}{\text{Initial weight}} \right) \times 100 \quad (5)$$

I. Data Analysis and Interpretation

Ten trials were conducted for each parameter, including weight, thickness, tensile strength, flexural strength, and impact resistance, to assess whether significant differences exist between coconut shell-based and mangosteen peel-based cellphone cases in terms of key performance indicators. The data gathered will indicate that both coconut shells and mangosteen peels possess favorable properties, such as durability and structural integrity, suggesting their suitability as alternatives to conventional materials. To evaluate the viability of these materials for use in cellphone cases production, the results will be compared with those from similar studies.

To ensure the reliability of the findings, data were analyzed and interpreted with statistical software StatKingdom based on the test results of the biocomposite characteristics. Normality of data was tested with Shapiro-Wilk test, whereas homogeneity was determined by Levene's test. If the significance level was greater than 5%, ANOVA was utilized; otherwise, a non-parametric test such as Kruskal-Wallis test was utilized.

III. RESULT AND DISCUSSION

The biocomposites were formulated using coconut shell powder and mangosteen peel powder as natural fillers, with Low-Density Polyethylene (LDPE) as a binder. These agricultural wastes were chosen to improve sustainability, reduce environmental impact, and utilize local biodegradable resources. Their mechanical and biodegradability properties were assessed through several tests including tensile strength, flexural strength, impact resistance, and biodegradation rate.

The production of these biocomposites aimed to evaluate how different combinations of coconut shell and mangosteen peel powders influence the final properties of the product. Based on the results of mechanical testing and biodegradability evaluation, Mixture 3 (28% Coconut Shell Powder, 42% Mangosteen Peel Powder, 30% LDPE) was found to be the optimal formulation. This mixture provided the best balance of tensile and flexural strength and biodegradability. The performance of Mixture 3 makes it the most suitable for consumer product applications such as cellphone casings that demand both durability and environmental responsibility.

Biocomposites, such as those derived from coconut shells and mangosteen peels, offer a promising alternative to synthetic plastics. While LDPE is known for its durability and water resistance, it lacks biodegradability. The three mixtures tested in this study vary in their ability to match the mechanical and environmental properties of LDPE. The properties of LDPE and biocomposites made from coconut shells and mangosteen peels were evaluated to highlight their advantages and drawbacks. Table 1 presents the ranking of mixtures based on each tested property

TABLE I. Ranks of Biocomposites

Properties	Mixture 1	Mixture 2	Mixture 3	LDPE
Weight	2	1	3	4
Thickness	3	2	1	4
Tensile Strength	1	2	3	4
Flexural Strength	3	1	2	4
Impact Resistance	1	3	2	4
Biodegradability	3	2	4	1
Total	13	11	15	21
Average	2.17	1.83	2.5	3.5

Note: 1 = Least desirable performance
 2 = Moderate performance
 3 = Most desirable performance
 4 = Ideal performance

The average scores indicate that Mixture 3 received an average score of 2.5, closely approaching LDPE with a score of 4.00, suggesting that it nearly matches the performance of LDPE across the selected parameters. In contrast, Mixture 1 had an average score of 2.17, while Mixture 2 followed with a score of 1.83. This indicates that Mixture 3 can be considered the most viable alternative to LDPE in applications that require

both durability and partial biodegradability. The consistent performance of Mixture 3 across multiple categories confirms its balanced formulation and practical utility. Additionally, the higher proportion of mangosteen peel may have enhanced both mechanical strength and biodegradation, contributing to its superior score.

Moreover, the cellphone casing produced from biocomposite material displayed commendable performance in terms of mechanical strength and protective function. While the surface texture was not completely smooth exhibiting some roughness due to fiber content and molding limitations it remained acceptable for prototype use. The casing successfully withstood everyday handling and minor drops, offering basic protection similar to conventional plastic cases. Despite the surface texture issues, the product showed potential for further refinement through process optimization or material blending, suggesting that biocomposites are a promising sustainable alternative for electronic accessories.



Figure 4. Cellphone Case

IV. CONCLUSION

This study successfully developed biocomposites utilizing coconut shell powder and mangosteen peel powder, with low-density polyethylene (LDPE) serving as a binder. The study specifically examined the effects of varying the ratios of coconut shell powder, mangosteen peel powder, and LDPE on the biodegradability, physical, and mechanical properties of the resulting biocomposites. Furthermore, it identified the optimal concentration necessary for the effective formulation of biocomposite strips intended for cellphone case fabrication. The primary objective of this study was to establish an initial understanding of material formulations, providing a foundation for future comprehensive experimental investigations aimed at the advancement of sustainable and durable biocomposite products.

Among the three, Mixture 1 and Mixture 2 recorded the highest average weight of 5.7 grams, while Mixture 3 had a slightly lower average weight of 5.4 grams, likely due to a higher content of less dense mangosteen peel powder. The ANOVA analysis results using the Kruskal-Wallis test showed a p-value of 0.2987, confirming that there is no statistically significant difference in the weight of the samples, indicating that the raw material composition does not meaningfully affect the weight.

The thickness measurements of the biocomposites showed that Mixture 1 recorded the thinnest average thickness at 42.6

mm, followed by Mixture 2 at 48.1 mm, and Mixture 3 exhibited the greatest thickness at 50.7 mm. The ANOVA analysis produced a p-value of 0.00003047, suggesting a statistically significant difference among the mixtures. A thinner biocomposite, such as Mixture 1, is preferable for cellphone case applications because it provides a lighter and more user-friendly design without making the case excessively bulky. Thus, achieving a balance between thickness and durability is crucial in the selection of the optimal biocomposite formulation.

The tensile strength testing revealed that Mixture 3 had the highest average tensile strength at 238.429 kPa, followed by Mixture 2 at 203.978 kPa, and Mixture 1 at 159.191 kPa. ANOVA analysis yielded a p-value of 4.229e-10, indicating a statistically significant difference, confirming that the raw material composition had a meaningful effect on tensile strength.

Flexural strength measurements showed Mixture 1 achieved the highest average flexural strength of 10,027 kPa, with Mixture 3 following at 9,054 kPa, and Mixture 2 recording the lowest at 6,466 kPa. Due to the non-normal distribution of data, the Kruskal-Wallis test was applied, and the resulting p-value of 0.00002288 confirmed a statistically significant difference, demonstrating that composition affects the flexural strength performance of the samples.

Impact resistance results indicated that Mixture 2 recorded the highest average impact resistance at 0.0706 Joules, followed by Mixture 1 at 0.0682 Joules, and Mixture 3 at 0.0646 Joules. The Kruskal-Wallis test resulted in a p-value below 0.05, confirming a significant difference in impact resistance between mixtures, suggesting that Mixture 2's composition provided the highest energy absorption upon impact.

The biodegradability test demonstrated that Mixture 3 exhibited the highest degradation rate at 80.5%, followed by Mixture 1 and then Mixture 2. The ANOVA analysis yielded a p-value of 0.000147, indicating a statistically significant difference among the three mixtures. Mixture 3's superior biodegradation rate is likely attributed to its higher proportion of mangosteen peel powder, which promotes faster natural decomposition. These findings highlight Mixture 3 as the most environmentally sustainable option for biocomposite applications.

The biocomposite cellphone casing fabricated using Mixture 3, comprising coconut and mangosteen peels, was identified as the most optimal formulation among all samples produced in this study. This mixture exhibited superior mechanical properties, including notable resistance to bending, impact, and tensile forces, thereby satisfying the essential performance criteria for protective electronic device casings. Furthermore, the material demonstrated an appropriate balance between structural integrity and biodegradability, ensuring functional reliability throughout its intended use while contributing to environmental sustainability. The overall surface quality, hardness, and user handling characteristics of the casing further reinforced its suitability for commercial application. These findings highlight the potential of agricultural waste materials, specifically coconut and mangosteen peels, as viable raw components in the development of eco-friendly alternatives to conventional plastic-based cellphone casings.

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